PUERTO RICO AND VIRGIN ISLANDS PRECIPITATION FREQUENCY STUDY

Update of *Technical Paper No. 42* and *Technical Paper No. 53*

Fourth Progress Report

Hydrometeorological Design Studies Center
Hydrology Laboratory

Office of Hydrologic Development
U.S. National Weather Service
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DISCLAIMER

Acknowledgments

Meteorologists, statisticians, computer experts and support staff have contributed to the Puerto Rico and Virgin Islands Precipitation Frequency Study. This includes, but is not limited to, the following people:

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1. Introduction.

The Hydrometeorological Design Studies Center (HDSC), Hydrology Laboratory, Office of Hydrologic Development, U.S. National Weather Service is updating its precipitation frequency analysis for Puerto Rico and the Virgin Islands. Current precipitation frequency studies for the area are contained in *Technical Paper No. 42* "Generalized estimates of probable maximum precipitation and rainfall-frequency data for Puerto Rico and Virgin Islands" (U.S. Weather Bureau 1961) and *Technical Paper No. 53* "Two- to ten-day rainfall for return periods of 2 to 100 years in Puerto Rico and Virgin Islands" (Miller 1965). The current study includes collecting data and performing quality control, compiling and formatting datasets for analyses, selecting applicable frequency distributions and fitting techniques, analyzing data, mapping and preparing reports and other documentation.

The study will determine annual and seasonal precipitation frequencies for durations from 5 minutes to 60 days, for return periods from 2 to 1000 years. The study will review and process all available rainfall data for the Puerto Rico and Virgin Island study area and use accepted statistical methods. The study results will be published as a Volume of NOAA Atlas 14. They will also be made available on the internet using web pages with the additional ability to download digital files.

The study area covers Puerto Rico and the U.S. Virgin Islands of St. Thomas, St. John and St. Croix. The study area is divided into 7 near-homogeneous climatic regions for analysis (Figure 1). Factors considered in defining the regions include 1) season(s) of highest precipitation, 2) type of precipitation (e.g., general storm, convective, tropical storms or hurricanes, or a combination), 3) climate, 4) topography and 5) homogeneity of these factors in a single area. The designated regions in this study have been confirmed by homogeneity tests. The regions are as follows:

- Region 1 constitutes the southern coast along the Carribean side of the island.
- Region 2 is the west-central low-lands portion of the island.
- Region 3 is the western mountain range including the highest portions of the island.
- Region 4 is the eastern mountain range.
- Region 5 encompasses El Yunque and the east-southeast portion of the island.
- Region 6 is the northern coastal plain and stretches from the east to west

coast.

- Region 7 includes of the islands surrounding Puerto Rico (Isla de Vieques, Isla de Culebra, and Isla Mona) and the U.S. Virgin Islands because there were no elevation differences between them and in general the same meteorological events affect the smaller islands equally.

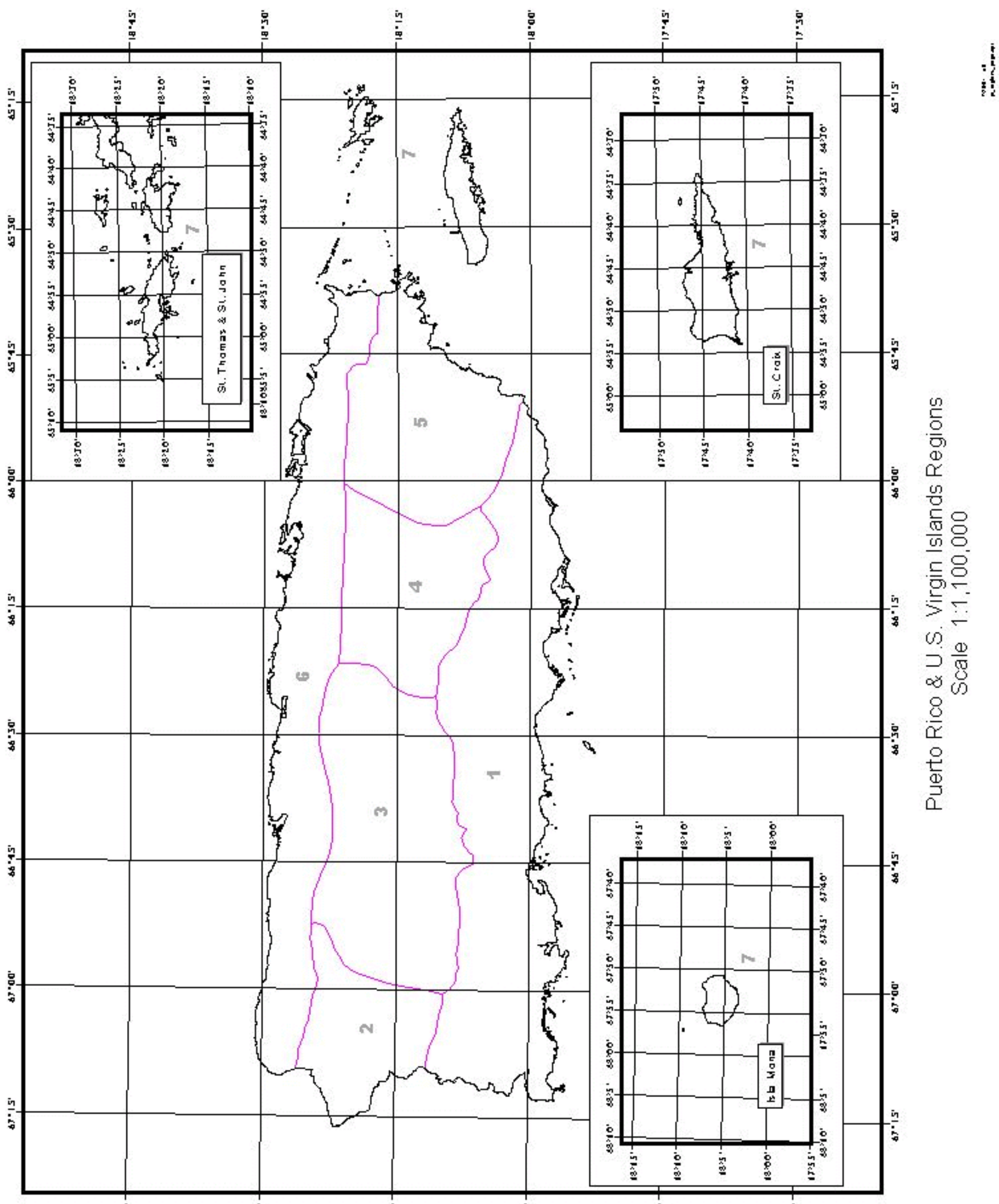

Figure 1. Puerto Rico Precipitation Frequency study area and region boundaries.

2. Highlights.

The daily, hourly, and n-minute datasets have been compiled and quality controlled through October 1998. Missing and accumulated values during 3 heavy rainfall events (Hurricanes Bertha, Hortense and Georges) were inspected and appropriate estimations of rainfall added to the daily dataset. 15-minute data from USGS was extensively quality controlled through April 1999. Data through December 2000 are currently being quality controlled and added to both the hourly and daily datasets. Additional information is provided in section 4.1, Update of Data Collection and Quality Control.

Maps of Maximum Recorded Precipitation for Puerto Rico and the Virgin Islands have been generated for 1-, 2-, 3-, 6-, 12- and 24-hour durations. Additional information is provided in section 4.2, Update of Maximum Recorded Precipitation Maps.

Work on an Internet-based Precipitation Frequency Data Server is near completion for the Semiarid Southwestern United States Precipitation Frequency Project. This will accommodate future studies including the Puerto Rico Study. Additional information is provided in section 4.3, Update of Precipitation Frequency Data Server.

The National Weather Service headquarters has reorganized, and the new management has initiated review of the Hydrometeorological Design Studies Center. Additional information is provided in section 5.1, Organizational Review by New Management.

3. Status.

3.1 Project Task List.

The following checklist shows the components of each task and an estimate of the percentage completed per task.

Puerto Rico study checklist [estimated percent complete]:

Data Collection, Formatting and Quality Control [90%]
- Daily
- Hourly
- N-minute

L-Moment Analysis/Frequency Distribution for 1 hr - 60 days and 2 to 1000 yrs [70%]
- Daily
- Hourly
- N-minute

Algorithm/Data Plot [15%]

- Establish regions from spatial, topographic and meteorological variables
- Run L-moments for regional growth factors to generate dataset
- Create 2yr-24hr precipitation frequency index map
    - Format dataset
    - Review maps (i.e., station id's, discordancy, elevation, frequency values)
    - Review hand-drawn analysis
    - Perform digitization
    - Rasterization
    - Generate contour rasters for final map
- Create ratio maps - 2yr (1-12) hr/2yr 24hr, 2yr (2-60) day/2yr 24hr
    - Plotting
    - Review hand-drawn analysis
    - Perform digitization
    - Rasterization
- Create regional growth factor maps - 2yr (1-12) hr/2yr 24hr, 2yr (2-60) day/2yr 24hr

Precipitation Frequency Maps [10%]

- Create frequency maps for 1-hour to 60-day durations at return periods 2 to 1000 years (seasonal and annual maximum) by multiplying index map rasters and using appropriate regional growth factor and ratio map rasters
- Create maps and/or relations for durations smaller than 1 hour (5, 10, 15, 30 minute) using index map and appropriate conversion factors
- Perform internal consistency checks (comparing rasters of sequential duration and frequency)

Temporal Distributions of Extreme Rainfall [0%]

- hourly data assembled by quartile of greatest precipitation amount and converted to cumulative rainfall amounts for each region
- graphs of representative storm-types and seasons

Spatial Relations (Depth-Area-Duration Studies) [0%]

- analyze critical storms to determine depth-area-duration relations
- small-area, short-duration relations
- area-depth curves for areas <500 mi^2 and for >500mi^2
- families of mass curves and area-depth curves as a function of duration and area size
- a smoothed set of curves to distinguish between convective, tropical and non-tropical storms (if appropriate)

Deliverables [5%]

- Write hard copy of Final Report
    - Maps of analyzed results
    - Graphical relations to obtain intermediate values
    - Seasonal variation
    - Depth-area distribution
    - Temporal distribution of rainfall in extreme storms
    - Implement peer review
- Prepare data for web delivery
- Prepare documentation for web delivery
- Publish hard copy of Final Report

3.1.1 Data Collection and Quality Control.

The daily and hourly datasets have been updated through October 1998; the 15-minute dataset through April 1999; and the n-minute dataset through May 1997. Table 1 shows the total number of stations in the study area. Complete station lists can be found in Appendix A. We are in the process of adding data to the daily and hourly stations through December 2000 and to the n-minute dataset through May 1998.

Table 1. Information on total daily, hourly and n-minute datasets through October 1998.

	Daily	**Hourly**	**USGS 15-minute**	**N-minute**
No. of stations	152	30*	103	1
Longest record length (yrs) (Station ID)	98 (66-0152, 66-2801, 66-4702)	32 (66-8812)	9 (67 stations have 9 yrs)	25 (66-8812)
Average record length (yrs)	45	23	8	25

*2 of the stations included in this total have less than 1 year of data and therefore were not included in the average record length

3.1.2 Statistical Analysis.

Frequency Distribution Fitting Analyses:

This task evaluates and selects the frequency distribution which provides the best fit for the data. A comprehensive L-moment statistical analysis (Hosking and Wallis 1997) of goodness-of-fit has been done on both daily and hourly data through October 1998 for all durations and all regions to select a best-fit distribution. The best-fit for the partial duration (PD) in this project is the Generalized Normal distribution (GNO) for daily precipitation frequency estimates and the Generalized Extreme Value (GEV) distribution for most hourly precipitation frequency estimates.

3.1.3 Mapping Analyses.

HDSC continues to explore the possibility of using spatial interpolation tools such as the Parameter-elevation Regressions on Independent Slopes Model (PRISM). Discussions with the Spatial Climate Analysis Center will determine if there are ways to adapt PRISM technology to precipitation frequency data.

3.1.4 Documentation and Publication.

The Puerto Rico and U.S. Virgin Island study results will be available on the HDSC Precipitation Frequency Data Server once mapping is complete. The Precipitation Frequency Data Server displays precipitation frequency values and intensity-duration-frequency curves and tables. At present, all 50 states and Puerto Rico/Virgin Islands can be selected. Where studies are not yet concluded, information on existing precipitation frequency maps and how to obtain them is given.

4. Progress since Last Reporting Period.

4.1 Update of Data Collection and Quality Control.

The compilation for the daily, hourly and n-minute datasets included merging stations where appropriate, and formatting for analysis. Generally, the criteria for merging stations are that stations must: 1) be within 100 feet in elevation, 2) be within 5 miles in distance, 3) contain a gap between records of 60 months (5 years) or less, and 4) contain an overlap in records of 60 months (5 years) or less. The data used in the merging are from the National Climatic Data Center (NCDC). These data were carefully inspected for similar precipitation regimes before being merged. 17 out of 118 daily stations in Puerto Rico and 3 of the 34 in the US Virgin Islands have merged records. Appendix B lists the daily station records that have been merged for this project. No hourly stations were merged. No 15-minute stations were merged because all of the records are overlapping the same time period. There is only one n-minute station.

The 15-minute stations were obtained from the United States Geological Survey (USGS) and required extensive formatting and quality control. A threshold value of 2.0 inches was selected to inspect extreme, possibly erroneous, 15-minute values. Through verification with near-by daily and hourly stations, values were either accepted or set to missing. Also, all data before July 1990 seemed questionable and it is likely that the stations were not yet fully operational at that time (correspondence with Matt Larson of USGS, Puerto Rico). Therefore, all data before July 1990 were deleted for all stations. Six stations were deleted entirely because their data was speculative. The deleted stations are listed in Appendix C.

Discrepancies in the daily dataset were identified. When we first compiled and formatted the data, the source data was inadequate - the last two days of months were invalid or missing. These missing values have since been added and updated in our database.

Other additions to the daily dataset have included estimated values during hurricanes where values were recorded as missing or accumulated. During extreme rainfall events, especially those associated with tropical systems, strong winds knock over gauges, or make them unusable for a variety of reasons. Often these gauges record no rainfall during this period thereby showing “missing” during a heavy rainfall event or values are not recorded for several days and so represent accumulated values. We mapped and examined hurricane events with a substantial number of missing or accumulated values. We interpolated reasonable yet conservative daily values for these lost data based on recorded values of nearby stations. While this addition does not increase the number of monthly maximum values per station it can increase the individual values used for the L-moment analysis. This becomes important when stations receive enough precipitation to exceed other maximum values used in the partial duration analysis. Since the Third Progress Report, three additional extreme rainfall events were mapped to estimate missing values or appropriately distribute accumulated values. The events were Hurricanes Bertha on 7/8/96, Hortense on 9/10/96, and Georges on 9/21/98. Additional daily data were interpolated for these storms. The added data are listed in Appendix D.

We generated a list of storm events that impacted the study area. The storms in this list are examined for missing and accumulated values, for possible use in depth-area-duration (DAD) analysis (for PMP as well as precipitation frequency), and for further synoptic and mesoscale analysis. We had previously identified eighty storms of tropical origin. Since the last Progress Report, 7 storms, including the 3 discussed above and several smaller events, were added to the list. Appendix E shows the compiled list.

Daily values were converted to 24-hour amounts. This conversion is necessary because of varying observation times for daily data, and the fact that the maximum 24-hour amounts seldom fall within a single daily observation period. Similarly, the hourly data were converted to 60 minutes. Conversion factors are determined from co-located stations. However, because there are so few co-located daily and hourly stations and only one n-minute station in Puerto Rico and Virgin Islands, we used the conversion factors from the Ohio River Basin. Table 2 shows the conversion factors used.

Table 2. List of conversion factors.

Daily Conversion Factors	1-day to 24-hour	**1.13**
	2-day to 48-hour	**1.04**
Hourly Conversion Factors	1-hour to 60-minute	**1.16**
	2-hour to 120-minute	**1.05**

Daily stations that have 20 years or more of data and hourly stations that have 15 years or more of data are used in the L-moment analyses to determine precipitation frequencies for the Puerto Rico study. If stations have less than the appropriate number of years of data, they are available for storm analysis or other investigation. Table 3 shows the number of daily and hourly stations used in the L-moment analysis for each region in the study area. A description of L-moment statistics can be found in Appendix F.

Table 3. Daily and hourly stations used in L-moment analysis.

Region	**Daily stations ≥ 20 years**	**Hourly stations ≥ 15 years**
1	28	2
2	7	1
3	22	5
4	9	4
5	19	9
6	20	2
7	28	3
total	**132**	**26**

An L-moment discordancy check for the current Puerto Rico daily data has been completed for all 7 regions. Stations with a discordancy value greater than or equal to 5.0 were flagged as suspicious or unusual. In the entire study area, no values were found to be discordant based on this threshold through October 1998. The discordancy check will be updated with the 1999 - 2000 data.

In summary, these analyses show that the quality control for the daily dataset through October 1998 for Puerto Rico and Virgin Islands has been thorough.

4.2 Update of Maximum Recorded Precipitation Maps

Maximum recorded values were extracted from the data base for all hourly stations for 1-, 2-, 3-, 6-, 12- and 24-hour durations and for all daily stations for 1-day durations. Using these data, maps of Maximum Recorded Precipitation at Puerto Rico and the Virgin Islands have been generated for 1-, 2-, 3-, 6-, 12- and 24-hour durations. The usefulness of including these maps in the final product will be evaluated once the maps have been reviewed. Through this task geospatial data and station locations were assessed. The maps showed that some current values of latitude and longitude for several stations may be incorrect. Also, the data that we are currently using for the geographical border of Puerto Rico may be inadequate. These issues will be resolved by the next reporting period.

4.3 Update of Precipitation Frequency Data Server

Work on the Internet-based Precipitation Frequency Data Server, which provides point and areal (up to 400 square miles) precipitation frequency data, is nearing completion. Though initiated for the Semiarid Southwest study, the Precipitation Frequency Data Server has been designed to accommodate future studies, such as the Ohio River and the Puerto Rico Precipitation Frequency Study. The Precipitation Frequency Data Server is capable of generating an Intensity-Duration Frequency (IDF) curve and data table on-the-fly.

The Precipitation Frequency Data Server has a point-and-click interface, which allows the user to move their mouse around a shaded relief map while the longitude, latitude and elevation values change in adjacent input boxes. The user also selects the desired units (U.S. or metric), season (warm, cool or all), and data type (Intensity-Duration-Frequency or precipitation frequency). Based on these selections and the latitude/longitude pair, a table and color-coded intensity-duration-frequency (IDF) curve or color-coded precipitation frequency bar graph are displayed. The Precipitation Frequency Data Server provides output for the entire duration list (5-min to 10-days) on a single output page. For those wishing to save the table data for further processing in, say a spreadsheet program, there is an option to save the data in a comma-delimited format. The output graph is a GIF file, which is both printable and savable.

5. Issues.

5.1 Organizational Review by New Management.

The National Weather Service headquarters has reorganized (details can be viewed at http://www.nws.noaa.gov/oh/start.html). The new management has initiated review of the Hydrometeorological Design Studies Center.

5.1.1 Technology

A committee of technical experts from our partners is reviewing the technology we are using for precipitation frequency analysis. The committee members are:

Rocky Durrans, The University of Alabama, Tuscaloosa, AL (Rapporteur)
Greg Johnson, USDA-NRCS National Water and Climate Center, Portland, OR
Lou Schreiner, U.S. Bureau of Reclamation, Lakewood, CO
Jim Angel, Illinois State Water Survey, Champaign, IL (representing the American Association of State Climatologists)
Art DeGaetano, Northeast Regional Climate Center, Ithaca, NY
Will Thomas, Michael Baker Corporation, Alexandria, VA (representing the Transportation Research Board)
David Goldman, U.S. Army Corps of Engineers, Davis, California
Alan McNab, National Climatic Data Center, Ashville, NC
Geoff Bonnin, NWS Office of Hydrologic Development, Silver Spring, MD (Chairman)

The committee is looking at:

1. Data Collection and Quality Control: The committee suggested NWS contract for the data collection and quality control work. To that end, the Northeast Regional Climate Center has submitted a proposal combining the expertise of each of the regional climate centers. Since the data collection and quality control work for the Puerto Rico Precipitation Frequency Study is almost complete, there will be no impact on this study.

2. Statistical Analysis Procedure: The committee recommended a panel of recognized experts review the procedures. The NWS is currently responding to the first round of review comments. The NWS expects the statistical analysis procedures to be validated with perhaps minor adjustments. We do not expect any impact on the Puerto Rico Frequency Study.

3. Spatial Interpolation: The committee recommended discussions with the Spatial Climate Analysis Center to determine if there are ways to adapt PRISM

technology to precipitation frequency data.

5.1.2 Funding and Schedule

The technical committee recommended that precipitation frequencies for the entire United States be updated within three years. While the management review is not yet final there is a significant concern about whether the funds available are consistent with these expectations and whether current schedules are realistic.

6. Projected Schedule.

The following list provides a tentative schedule with completion dates. Brief descriptions of tasks being worked on in the next 2 quarters are also included in this section.

Data Collection and Quality Control [September 2001]
L-Moment Analysis/Frequency Distribution [November 2001]
Algorithm/Data Plot [December 2001]
Precipitation Frequency Maps [February 2002]
Temporal Distributions of Extreme Rainfall [April 2002]
Spatial Relations (Depth-Area-Duration Studies) [April 2002]
Implement Precipitation Frequency Data Server [April 2002]
Implement review by peers [May 2002]
Write hard copy of Final Report [June 2002]
Publish hard copy of Final Report [August 2002]

6.1 Data Collection and Quality Control.

Daily and hourly station data up through December 2000 will be added to the dataset and included in the precipitation frequency calculations. One additional year of n-minute data is available and will be added to the dataset. The tasks involved with data collection, formatting and quality control will take roughly 3 weeks for all regions in the Puerto Rico and Virgin Islands study area.

6.2 L-Moment Analysis/Frequency Distribution.

A comprehensive L-moment statistical analysis will be done on both daily and hourly data through December 2000 for all durations and all regions to select a best-fit distribution. The tasks involved with the statistical analysis will take roughly one month for the Puerto Rico and Virgin Islands study area.

6.3 Precipitation Frequency Maps.

The next step is the mapping analysis. This process is a combined hand-analysis and computer mapping technique that creates an *Index Map*, determines its relation to other durations and/or return frequencies, and uses the computer and GIS techniques to do the arithmetic to generate other maps of interest. The 2-year, 24-hour map (*Index Map*) will be hand-analyzed from exactingly quality-controlled data, and return-frequency values computed using L-moment statistical software over near-homogeneous climatic regions. The 2-year, 24-hour map is used as the *Index Map* because the 24-hour information is most directly observed, has the most stations, and has the longest periods of record.

The *Index Map* will be multiplied by the appropriate regional growth factors (RGFs) for the 24-hour return frequency of interest. Since the RGFs are defined relative to the mean value (and not 2-year values), the RGFs for return frequencies other than 2-year, 24-hour must be divided by the 2-year, 24-hour RFGs; and then this ratio is used as the multiplier to define the intensity for a particular return frequency. To produce maps of less than 24-hour duration, the *Index Map* is spatially multiplied by ratios of hourly values to 24-hour values. The process is illustrated in Diagram 1. Similarly, seasonal maps will based on the ratio of the warm (or cool) season to the all-season 2-year maps for 1-hour, 6-hour, and 24-hour durations. The process is illustrated in Diagrams 2a and 2b. Ratio maps of warm (or cool) season to all-season values for longer durations (2-, and 4-day) at 2-year and 100-year return frequencies will be included.

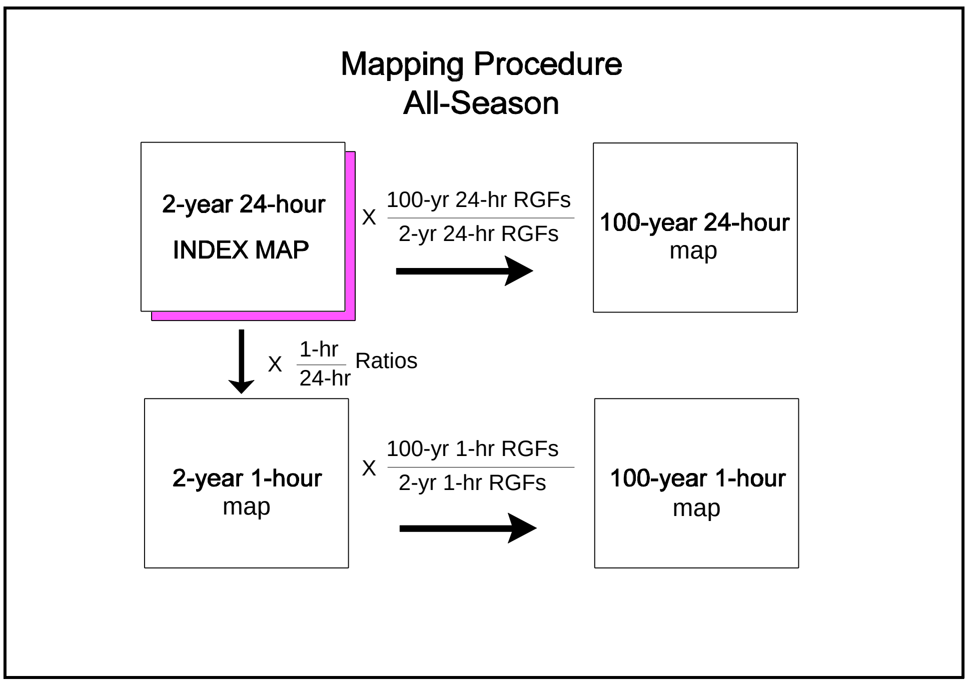

Diagram 1. *Flow chart of all-season mapping procedure.*

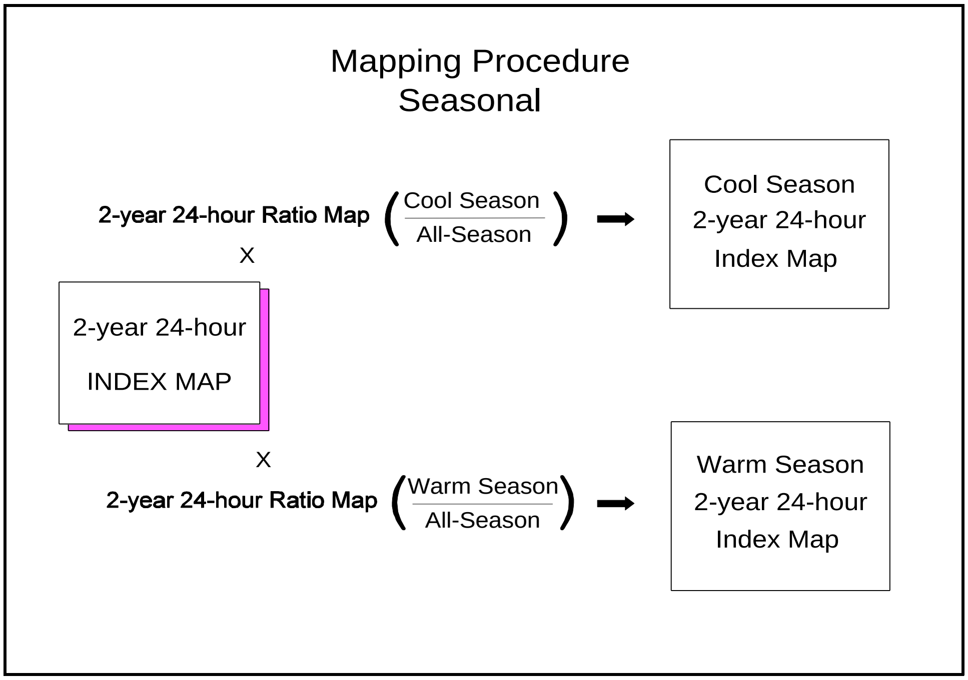

Diagram 2a. *Flow chart of seasonal mapping procedure.*

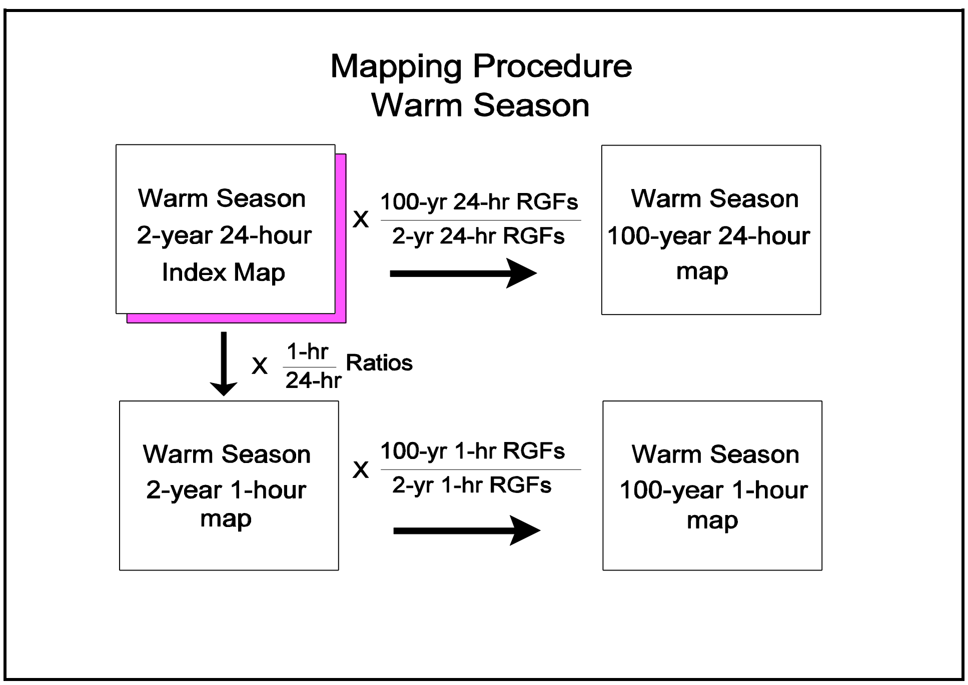

Diagram 2b. *Flow chart of warm season mapping procedure.*

To produce the final product, a sophisticated cartographic-map making process has been designed using the latest release of ArcView. During the next few months the review and revision process will result in a final cartographic-quality map template. This map template will then serve as the basis for all future precipitation frequency maps. The maps will be available both online (as ArcInfo ASCII raster, ArcView GIS shapefile, postscript and JPEG files) and in a hardcopy form with the final reports.

6.4 Precipitation Frequency Data Server.

Once the data and mapping are finalized, the precipitation frequency estimates for the Puerto Rico study will be available from the newly developed HDSC web-based Precipitation Frequency Data Server. The Precipitation Frequency Data Server will display precipitation frequency values, as well as intensity-duration-frequency (IDF) curves and tables. Eventually, all 50 states and Puerto Rico/Virgin Islands will be selectable from the opening U.S. map.

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Hershfield, D.M., 1961: Rainfall frequency atlas of the United States for durations from 30 minutes to 24 hours and return periods from 1 to 100 years, *Weather Bureau Technical Paper No. 40*, U.S. Weather Bureau. Washington, D.C., 115 pp.

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Appendix A. Station Inventories for Puerto Rico and U.S. Virgin Islands.

A.1. Daily stations

Station Name	ID	Lat	Long	Elev	Start Date	End Date	Region
ACEITUNA	66-0040	18.15	66.50	2140	01/1949	10/1998	1
ADJUNTAS 1 NW	66-0053	18.18	66.73	1500	05/1899	10/1998	3
ADJUNTAS SUBSTN	66-0061	18.18	66.80	1830	01/1970	10/1998	3
AGUIRRE CENTRAL	66-0152	17.97	66.22	20	07/1899	10/1998	1
AIBONITO	66-0158	18.13	66.25	2100	01/1905	10/1998	4
ARECIBO 3 ESE	66-0410	18.45	66.68	10	02/1900	10/1998	6
ARECIBO OBSERVATORY	66-0426	18.35	66.77	1060	02/1930	10/1998	3
BARCELONETA 2	66-0662	18.47	66.50	10	04/1915	12/1989	6
BARRANQUITAS	66-0736	18.17	66.32	2060	01/1943	12/1987	4
BENAVENTE-HORMIGUEROS	66-0900	18.12	67.10	40	01/1900	12/1991	1
BORINQUEN AIRPORT	66-0974	18.50	67.13	230	01/1941	10/1998	6
CABO ROJO	66-1123	18.08	67.15	250	01/1909	12/1968	1
CACAOS-OROCOVIS	66-1142	18.23	66.50	1820	05/1981	10/1998	3
CAGUAS 1 W	66-1309	18.23	66.05	260	01/1900	12/1994	5
CALERO CAMP	66-1345	18.48	67.12	250	09/1928	10/1998	6
CANDELARIA TOA BAJA	66-1536	18.42	66.23	240	05/1899	08/1995	6
CANOVANAS	66-1590	18.38	65.90	40	01/1901	10/1998	6
CAONILLAS UTUADO	66-1623	18.28	66.65	850	01/1949	11/1987	3
CAONILLAS VILLALBA	66-1634	18.12	66.48	600	01/1950	09/1969	1
CARITE DAM	66-1701	18.08	66.10	1810	06/1911	12/1979	4
CARITE PLANT 1	66-1712	18.05	66.12	970	01/1949	12/1977	1
CATANO	66-1845	18.42	66.12	20	01/1942	12/1975	6
CAYEY 1 E	66-1901	18.12	66.15	1370	01/1899	10/1998	4
CENTRAL SAN FRANCISCO	66-2316	17.98	66.82	30	09/1928	12/1995	1
CERRO GORDO CIALES	66-2330	18.28	66.52	960	01/1970	09/1997	3
CERRO MARAVILLA	66-2336	18.15	66.55	4000	04/1969	10/1998	3
CIDRA 1 E	66-2634	18.18	66.15	1400	01/1900	12/1992	4
COAMO_	66-2723	18.07	66.38	240	01/1921	10/1998	1
COLOSO	66-2801	18.38	67.15	40	07/1899	10/1998	2
COMERIO FALLS PLANT 2	66-2825	18.27	66.18	370	01/1908	12/1972	4
COROZAL SUBSTN	66-2934	18.33	66.37	650	01/1931	10/1998	3
CORRAL VIEJO	66-3023	18.07	66.65	400	04/1970	10/1998	1
CULEBRA ISLAND	66-3145	18.30	65.28	50	01/1938	12/1974	7
DORADO 2 WNW	66-3409	18.47	66.30	60	01/1908	09/1998	6
DOS BOCAS	66-3431	18.33	66.67	200	01/1937	10/1998	3
ENSENADA	66-3532	17.97	66.93	10	01/1923	10/1998	1
FAJARDO	66-3657	18.32	65.65	30	01/1899	12/1995	6
GUAJATACA DAM	66-3904	18.40	66.93	680	01/1929	10/1998	2
GUAVATE CAMP	66-4115	18.12	66.07	2560	01/1970	12/1993	4
GUAYABAL	66-4126	18.07	66.48	370	01/1912	10/1998	1
GUAYAMA	66-4193	17.98	66.12	180	01/1902	10/1998	1
GURABO	66-4271	18.25	65.97	250	01/1944	12/1966	5
GURABO SUBSTN	66-4276	18.25	66.00	160	03/1956	10/1998	5
HACIENDO CONSTANZA	66-4330	18.22	67.08	480	01/1970	10/1998	2

HATO ARRIBA ARECIBO	66-4340	18.45	66.77	210	02/1974	08/1994	6
HUMACOA 2 SSE	66-4613	18.13	65.82	90	01/1900	12/1995	5
INDIERA ALTA	66-4677	18.17	66.88	2600	01/1953	12/1989	3
INDIERA BAJA	66-4685	18.18	66.90	2800	11/1952	09/1962	3
ISABELA SUBSTATION	66-4702	18.47	67.07	420	01/1899	10/1998	6
JAJOME ALTO	66-4867	18.08	66.15	2390	01/1914	10/1998	1
JAYUYA	66-4910	18.22	66.60	1540	01/1909	10/1998	3
JOSEFA	66-4976	17.97	66.15	30	01/1911	12/1968	1
JUANA DIAZ CAMP	66-5020	18.05	66.50	200	01/1901	10/1998	1
JUNCOS 1 NNE	66-5064	18.25	65.92	180	01/1931	10/1998	5
LA FE	66-5075	18.23	65.77	150	01/1925	12/1967	5
LAJAS SUBSTN	66-5097	18.05	67.05	90	01/1948	10/1998	1
LA MUDA CAGUAS	66-5123	18.32	66.10	290	09/1971	12/1992	4
LARES 2 SE	66-5175	18.28	66.85	1520	06/1903	12/1990	3
LOS CANOS	66-5474	18.43	66.72	30	01/1950	08/1973	6
MAGUEYES ISLAND	66-5693	17.97	67.05	20	01/1959	09/1998	1
MANATI 3 E	66-5807	18.43	66.45	250	01/1900	10/1998	6
MARICAO	66-5906	18.18	66.98	1500	01/1908	12/1968	3
MARICAO 2 SSW	66-5908	18.15	66.98	2830	05/1969	10/1998	3
MARICAO FISH HATCHERY	66-5911	18.17	66.98	1500	01/1955	10/1998	3
MATRULLAS DAM	66-6017	18.22	66.48	2450	01/1932	12/1980	3
MAUNABO	66-6050	18.02	65.90	40	01/1900	08/1998	1
MAYAGUEZ CITY	66-6073	18.17	67.13	60	06/1899	10/1998	2
MAYAGUEZ AIRPORT	66-6083	18.25	67.15	40	01/1957	09/1998	2
MELANIA DAM	66-6128	17.98	66.15	140	01/1949	12/1968	1
MONA ISLAND	66-6255	18.08	67.85	170	02/1918	12/1972	7
MONA ISLAND 2	66-6258	18.10	67.93	10	02/1980	08/1998	7
MONTE BELLO MANATI	66-6270	18.38	66.52	640	01/1970	10/1998	3
MORA CAMP	66-6361	18.47	67.03	410	01/1931	10/1998	6
MOROVIS 1 N	66-6390	18.33	66.40	600	02/1956	10/1998	3
NAGUABO 3 E	66-6427	18.22	65.68	70	01/1925	12/1982	5
NAGUABO 6 W	66-6432	18.23	65.73	100	01/1909	12/1966	5
NEGRO-COROZAL	66-6514	18.33	66.33	1710	03/1963	10/1998	4
PARAISO	66-6805	18.27	65.72	330	01/1926	10/1998	5
PATILLAS DAM	66-6904	18.03	66.03	240	01/1912	12/1968	1
PENUELAS SALTO GARZAS	66-6982	18.08	66.73	1150	01/1949	12/1969	1
PENUELAS 1 NE	66-6983	18.07	66.72	320	01/1920	10/1998	1
PICO DEL ESTE	66-6992	18.27	65.75	3450	01/1970	10/1998	5
PONCE 4 E	66-7292	18.02	66.53	70	01/1909	10/1998	1
PONCE CITY	66-7295	17.98	66.63	10	05/1900	08/1998	1
PUERTO REAL	66-7492	18.08	67.18	30	01/1944	08/1998	1
QUEBRADILLAS	66-7843	18.47	66.93	370	04/1924	10/1998	6
RINCON POWER PLANT	66-8126	18.35	67.25	80	01/1958	07/1998	2
RIO BLANCO LOWER	66-8144	18.25	65.78	130	01/1941	10/1998	5
RIO BLANCO UPPER	66-8155	18.28	65.78	1440	01/1904	12/1973	5
RIO CANAS	66-8178	18.03	66.47	190	01/1949	12/1969	1
RIO GRANDE EL VERDE	66-8245	18.33	65.82	600	01/1912	12/1984	5
RIO JUEYES	66-8278	18.02	66.35	140	04/1949	12/1968	1
RIO PIEDRAS EXP STN	66-8306	18.40	66.05	90	01/1911	10/1998	6
ROOSEVELT ROADS	66-8412	18.25	65.63	40	01/1960	10/1998	5

SABANA GRANDE 2 ENE	66-8535	18.08	66.93	660	06/1928	12/1952	1
SABANA GRANDE 2 ENE	66-8536	18.08	66.93	850	01/1966	10/1998	1
SABATER	66-8623	17.98	66.23	70	01/1949	12/1968	1
ST JUST	66-8634	18.38	66.00	100	03/1943	12/1966	6
SALTILLO 2 ADJUNTAS	66-8684	18.13	66.73	2850	01/1939	12/1991	3
SAN JUAN CITY	66-8808	18.47	66.10	20	01/1899	05/1977	6
SAN JUAN WSFO	66-8812	18.43	66.00	10	01/1956	10/1998	6
SAN LORENZO 3 S	66-8815	18.15	65.97	510	01/1969	10/1998	5
SAN LORENZO ESPINO	66-8817	18.10	66.00	1270	01/1900	12/1958	5
SAN LORENZO FARM 2 NW	66-8822	18.20	65.97	240	01/1925	12/1987	5
SAN SEBASTIAN 2 WNW	66-8881	18.35	67.02	170	01/1908	10/1997	2
SANTA ISABEL 2 ENE	66-8940	17.97	66.37	30	06/1901	10/1998	1
SANTA RITA	66-8955	18.03	66.88	70	01/1903	10/1998	1
TOA BAJA 1 SSW	66-9421	18.43	66.27	20	04/1926	08/1994	6
TORO NEGRO FOREST	66-9432	18.18	66.50	2850	01/1929	10/1998	3
TORO NEGRO PLANT 2	66-9466	18.17	66.52	2250	06/1911	07/1981	3
TRUJILLO ALTO 2 SSW	66-9521	18.33	66.02	130	02/1957	10/1998	5
UTUADO	66-9608	18.27	66.68	520	06/1920	07/1998	3
VIEQUES SUGAR CO	66-9700	18.10	65.55	30	01/1925	12/1943	7
VIEQUES ISLAND #2	66-9766	18.12	65.43	250	05/1899	12/1993	7
VILLALBA 1 E	66-9774	18.13	66.48	550	01/1941	10/1998	1
YABUCOA 1 NNE	66-9829	18.07	65.87	30	07/1971	10/1998	5
YAUCO 1 NW	66-9860	18.05	66.87	180	01/1900	10/1998	1
YAUREL 3 NNE	66-9884	17.98	66.07	130	01/1948	12/1968	1
ST CROIX FAA HAMILTO	67-0198	17.70	64.80	20	01/1972	10/1998	7
ANNALY	67-0240	17.75	64.85	700	01/1972	10/1998	7
ANNAS HOPE	67-0260	17.73	64.95	180	01/1972	12/1987	7
BETH UPPER NEW WORKS	67-0480	17.72	64.80	110	01/1972	10/1998	7
BORDEAUX MOUNTAIN	67-0820	18.33	64.73	1110	01/1972	07/1984	7
CANE BAY	67-1310	17.78	64.82	80	01/1972	07/1975	7
CANEEL BAY PLANTATION	67-1316	18.35	64.78	60	01/1972	02/1998	7
CATHERINBURG	67-1348	18.35	64.75	800	01/1972	11/1996	7
CHARLOTTE AMALIE 2	67-1625	18.35	64.93	10	01/1972	11/1981	7
CHRISTIANSTED FORT	67-1740	17.75	64.70	40	01/1972	07/1995	7
CORAL BAY	67-1790	18.33	64.70	30	01/1972	09/1998	7
COTTON VALLEY 2	67-1810	17.75	64.62	140	03/1972	10/1998	7
CRUZ BAY	67-1980	18.33	64.80	10	01/1972	10/1998	7
DOROTHEA AG EXPERIMENT	67-2440	18.37	64.97	800	01/1972	12/1992	7
EAST END	67-2551	18.33	64.68	150	01/1972	07/1997	7
EAST HILL	67-2560	17.77	64.65	120	01/1972	10/1998	7
ESTATE FORT MYLNER	67-2823	18.33	64.88	200	01/1972	08/1995	7
ESTATE HOPE	67-2830	18.37	65.00	390	05/1984	08/1989	7
ESTATE PEARL	67-2850	18.37	64.98	880	03/1979	05/1979	7
ESTATE RUST-OP-TWIST	67-2860	17.78	64.78	50	08/1976	07/1984	7
ESTATE THE SIGHT	67-2870	17.75	64.67	130	01/1972	10/1998	7
FOUNTAIN	67-3150	17.75	64.83	250	01/1972	04/1992	7
FREDERIKSTED 1 SE	67-3220	17.70	64.87	80	01/1972	08/1989	7
FRENCHMANS BAY	67-3380	18.32	64.92	120	01/1972	02/1978	7
GOOD HOPE SCHOOL	67-3609	17.68	64.85	10	01/1972	12/1975	7
GRANARD	67-3677	17.72	64.72	120	01/1972	10/1998	7

HAM BLUFF LIGHT HOUSE	67-3880	17.77	64.87	80	01/1972	10/1992	7
LAMESHUR BAY	67-4820	18.32	64.73	170	01/1972	12/1988	7
MONTPELLIER	67-4900	17.77	64.75	200	01/1972	10/1998	7
RED HOOK BAY	67-7600	18.32	64.85	10	03/1980	10/1998	7
TAGUE BAY	67-8621	17.75	64.60	30	03/1972	05/1981	7
CHARLOTTE AMALIE HAR	67-8905	18.35	64.97	10	09/1972	06/1996	7
WATER ISLE	67-9222	18.32	64.95	100	01/1972	07/1990	7
WINTBERG	67-9450	18.35	64.92	560	01/1972	10/1998	7

A.2. Hourly stations

Station Name	ID	Lat	Long	Elev	Start Date	End Date	Region
ADJUNTAS SUBSTN	66-0061	18.18	66.80	1830	07/1971	10/1998	3
BENAVENTE-HORMIGUEROS	66-0900	18.12	67.10	40	07/1973	10/1998	1
BOTIJAS 1 OROCOVIS	66-0984	18.25	66.37	1840	06/1973	10/1998	4
BOTIJAS 2 OROCOVIS	66-0988	18.22	66.37	2230	06/1973	10/1998	4
CAYEY 1 E	66-1901	18.12	66.15	1370	07/1971	10/1998	4
CERRO MARAVILLA	66-2336	18.15	66.55	4000	07/1971	10/1998	3
COROZAL SUBSTN	66-2934	18.33	66.37	650	07/1971	10/1998	3
CUBUY	66-3113	18.27	65.87	1650	05/1973	10/1998	5
DOS BOCAS	66-3431	18.33	66.67	200	07/1971	10/1998	3
OUQUE 2 NE	66-3480	18.27	65.72	450	05/1973	10/1998	5
FAJARDO	66-3657	18.32	65.65	30	07/1971	10/1998	6
GURABO 2 NNE	66-4272	18.28	65.80	1380	05/1973	10/1998	5
GURABO SUBSTN	66-4276	18.25	66.00	160	07/1971	10/1998	5
LAS PIEDRAS 1 N	66-5258	18.20	65.87	300	06/1973	10/1998	5
MARICAO 2 SSW	66-5908	18.15	66.98	2830	07/1971	10/1998	3
NEGRO-COROZAL	66-6514	18.33	66.33	1710	06/1973	10/1998	4
PENA POBRE NAGUABO	66-6942	18.22	65.83	330	05/1973	10/1998	5
PICO DEL ESTE	66-6992	18.27	65.75	3450	05/1973	10/1998	5
PONCE 4 E	66-7292	18.02	66.53	70	07/1971	10/1998	1
SAN GERMAN 4 W	66-8757	18.08	67.10	90	07/1971	07/1973	1
SAN JUAN WSFO	66-8812	18.43	66.00	10	01/1967	10/1998	6
SAN LORENZO 2 ESE	66-8816	18.18	65.93	460	05/1973	10/1998	5
SAN SEBASTIAN 2 WNW	66-8881	18.35	67.02	170	07/1971	10/1998	2
YABUCOA 1 NNE	66-9829	18.07	65.87	30	07/1971	10/1998	5
BETH UPPER NEW WORKS	67-0480	17.72	64.80	110	12/1978	10/1998	7
CANEEL BAY PLANTATION	67-1316	18.35	64.78	60	11/1978	10/1998	7
DOROTHEA AG EXPERIMENT	67-2440	18.37	64.97	800	09/1979	10/1993	7
ESTATE PEARL	67-2850	18.37	64.98	880	11/1978	08/1979	7
-STATION NAME MISSING-	67-3440	0.00	0.00	-999	01/1984	01/1984	7
-STATION NAME MISSING-	67-4060	0.00	0.00	-999	04/1979	04/1979	7

A.3. 15-minute Stations

Station Name	ID	Lat	Long	Elev	Start Date	End Date	Region
RIO GUAJATACA AT LARES	01-0500	18.30	66.87	285	07/1990	04/1999	3
LAGO GUAJATACA AT DAMSIT	01-0800	18.40	66.92	201	04/1995	04/1999	2
RIO CAMUY NR BAYANEY	01-4800	18.40	66.82	104	07/1990	04/1999	3
LAGO GARZAS NR ADJUNTAS	02-0100	18.13	66.73	736	07/1990	04/1999	3
RIO GRANDE DE ARECIBO AB	02-1700	18.23	66.72	150	07/1990	04/1999	3
RIO GRANDE DE ARECIBO BL	02-4950	18.30	66.70	90	04/1996	04/1999	3
RIO SALIENTE AT COABEY N	02-5155	18.22	66.57	520	07/1990	04/1999	3
RIO CAONILLAS AT PASO PA	02-6025	18.23	66.63	294	01/1996	04/1999	3
LAGO CAONILLAS AT DAMSIT	02-6140	18.28	66.65	252	03/1991	04/1999	3
RIO GRANDE DE ARECIBO AB	02-7750	18.42	66.70	9	07/1990	04/1999	6
RIO TANAMA AT CHARCO HON	02-8400	18.42	66.72	18	04/1996	09/1998	6
RIO OROCOVIS NR OROCOVIS	03-0460	18.22	66.40	152	07/1990	04/1999	4
RIO GRANDE DE MANATI NR	03-1200	18.30	66.42	134	07/1990	04/1999	3
LAGO EL GUINEO AT DAMSIT	03-2290	18.17	66.53	902	07/1990	04/1999	3
LAGO DE MATRULLAS AT DAM	03-2590	18.22	66.48	736	07/1990	04/1999	3
RIO BAUTA NR OROCOVIS	03-4000	18.23	66.45	236	07/1990	04/1999	3
RIO GRANDE DE MANATI AT	03-5000	18.32	66.47	43	07/1990	04/1999	3
RIO GRANDE DE MANATI AT	03-8100	18.43	66.53	4	07/1990	04/1999	6
RIO CIBUCO BLW COROZAL	03-8320	18.35	66.33	59	07/1990	04/1999	4
RIO CIBUCO AT VEGA BAJA	03-9500	18.45	66.37	3	07/1990	04/1999	6
LAGO CARITE AT GATE TOWE	03-9990	18.07	66.10	544	07/1990	04/1999	4
RIO DE LA PLATA AT PROYE	04-3000	18.17	66.23	259	07/1990	04/1999	4
RIO DE LA PLATA AT COMER	04-3800	18.22	66.23	184	07/1990	04/1999	4
RIO GUADIANA AT GUADIANA	04-4830	18.32	66.22	70	09/1990	04/1999	4
LAGO LA PLATA AT DAMSITE	04-5000	18.35	66.23	47	07/1990	04/1999	4
RIO DE LA PLATA AT HWY 2	04-6000	18.42	66.27	3	07/1990	04/1999	6
LAGO CIDRA AT DAMSITE NR	04-7550	18.20	66.13	405	07/1990	04/1999	4
RIO DE BAYAMON BLW LAGO	04-7560	18.20	66.13	390	12/1990	04/1999	4
RIO DE BAYAMON NR BAYAMO	04-7850	18.33	66.13	30	07/1990	04/1999	4
LAGO LAS CURIAS AT DAMSI	04-8680	18.40	66.05	100	01/1998	04/1999	6
RIO PIEDRAS AT EL SENORI	04-8770	18.37	66.07	30	02/1991	04/1999	6
RIO PIEDRAS AT HATO REY	04-9100	18.42	66.07	5	01/1994	04/1999	6
RIO GRANDE DE LOIZA AT Q	05-0900	18.12	65.98	195	07/1990	04/1999	5
QUEBRADA BLANCA AT EL JA	05-1150	18.17	65.98	140	07/1990	04/1999	5
QUEBRADA SALVATIERRA NR	05-1180	18.17	65.98	100	07/1990	04/1999	5
RIO CAYAGUAS AT CERRO GO	05-1310	18.15	65.95	150	07/1990	04/1999	5
RIO GRANDE LOIZA AT HWY	05-1800	18.18	65.97	80	07/1990	04/1999	5
RIO TURABO ABOVE BORINQU	05-3025	18.17	66.03	150	07/1990	04/1999	5
RIO GRANDE DE LOIZA AT C	05-5000	18.25	66.02	44	07/1990	04/1999	5
RIO CAGUITAS NR AGUAS BU	05-5100	18.25	66.10	120	07/1990	04/1999	4
RIO CAGUITAS AT VILLA BL	05-5225	18.25	66.03	50	04/1991	04/1999	5
RIO BAIROA AT BAIROA	05-5390	18.27	66.03	40	12/1990	04/1999	5
RIO GURABO BLW EL MANGO	05-5750	18.23	65.88	70	07/1990	04/1999	5
RIO VALENCIANO NR JUNCOS	05-6400	18.22	65.93	98	07/1990	04/1999	5
RIO GURABO AT GURABO	05-7000	18.27	65.97	40	07/1990	04/1999	5
RIO CANAS AT RIO CANAS	05-8350	18.30	66.05	50	07/1990	04/1999	4
RIO GRANDE DE LOIZA BLW	05-9050	18.35	66.00	10	07/1990	04/1999	5
RIO CANOVANAS NR CAMPO R	06-1800	18.32	65.88	68	01/1993	04/1999	5

RIO ESPIRITU SANTO NR EL	06-3800	18.37	65.82	12	07/1994	04/1999	6
RIO GRANDE NR EL VERDE	06-4200	18.35	65.85	40	09/1990	04/1999	6
RIO MAMEYES NR SABANA	06-5500	18.33	65.75	84	03/1991	04/1999	6
RIO MAMEYES AT MAMEYES	06-6000	18.37	65.77	5	07/1997	04/1999	6
RIO SABANA AT SABANA	06-7000	18.33	65.73	80	03/1991	04/1999	6
RIO FAJARDO ABV FAJARDO	07-0500	18.25	65.72	100	11/1995	04/1999	5
RIO FAJARDO NR FAJARDO	07-1000	18.30	65.70	42	07/1990	04/1999	6
QUEBRADA GUABA NR NAGUAB	07-4950	18.28	65.78	645	10/1993	04/1999	5
RIO ICACOS NR NAGUABO	07-5000	18.28	65.78	628	07/1992	04/1999	5
RIO HUMACAO AT LAS PIEDR	08-1000	18.17	65.87	79	07/1990	04/1999	5
RIO MAUNABO AT LIZAS	09-0500	18.03	65.93	70	02/1991	04/1999	1
RIO GRANDE DE PATILLAS N	09-2000	18.03	66.03	72	07/1990	04/1999	1
LAGO PATILLAS AT DAMSITE	09-3045	18.02	66.02	70	03/1995	04/1999	1
RIO COAMO AT COAMO	10-6100	18.08	66.35	110	07/1990	04/1999	1
RIO TOA VACA ABV LAGO TO	11-0900	18.13	66.45	160	07/1990	04/1999	1
LAGO TOA VACA AT DAMSITE	11-1210	18.10	66.48	162	08/1997	04/1999	1
LAGO GUAYABAL AT DAMSITE	11-1300	18.08	66.50	100	04/1995	04/1999	1
RIO JACAGUAS AT JUANA DI	11-1500	18.05	66.52	40	07/1990	04/1999	1
RIO INABON AT REAL ABAJO	11-2500	18.08	66.57	125	07/1990	04/1999	1
RIO CERRILLOS ABV LAGO C	11-3800	18.12	66.60	210	07/1990	04/1999	1
LAGO CERRILLOS AT DAMSIT	11-3950	18.08	66.58	194	08/1991	04/1999	1
RIO CERRILLOS NR PONCE	11-4000	18.07	66.58	77	08/1991	04/1999	1
RIO BUCANA AT HWY 14 BRI	11-4390	18.03	66.58	36	07/1990	04/1999	1
RIO PORTUGUES AT TIBES	11-4900	18.10	66.65	76	10/1997	04/1999	1
RIO PORTUGUES NR PONCE	11-5000	18.08	66.63	143	07/1990	01/1999	1
RIO PORTUGUES AT HWY 14	11-5900	18.02	66.60	20	06/1997	04/1999	1
RIO GUAYANILLA NR GUAYAN	12-4200	18.05	66.80	24	07/1990	04/1999	1
LAGO LUCHETTI AT DAMSITE	12-5780	18.10	66.87	174	07/1990	04/1999	1
LAGO LOCO AT DAMSITE NR	12-8900	18.05	66.88	75	05/1995	04/1999	1
RIO GUANAJIBO AT HWY 119	13-1990	18.08	67.03	45	04/1991	04/1999	1
RIO ROSARIO NR HORMIGUER	13-6400	18.17	67.08	15	07/1990	04/1999	1
RIO GUANAJIBO NR HORMIGU	13-8000	18.15	67.15	14	07/1990	04/1999	1
LAGO GUAYO AT DAMSITE NR	14-1500	18.22	66.83	445	07/1990	04/1999	3
RIO GRANDE DE ANASCO NR	14-4000	18.28	67.05	32	07/1990	04/1999	2
RIO CULEBRINAS AT HWY 40	14-7800	18.37	67.10	14	09/1990	04/1999	2
RAINGAGE AT NASD AT VIEQ	23-0503	18.13	66.52	9	04/1997	04/1999	1
BONNE RESOLUTION GUT AT	25-2000	18.37	64.97	85	05/1992	04/1999	7
RG. AT NATIONAL PARK SER	26-5001	18.33	64.85	2	07/1992	04/1999	7
TURPENTINE RUN AT MT ZIO	27-4000	18.33	64.88	27	12/1992	04/1999	7
GUINEA GUT AT BETHANY, S	29-5000	18.33	64.78	79	04/1992	04/1999	7
JOLLY HILL GUT AT JOLLY	34-5000	17.73	64.87	43	06/1995	04/1999	7
QUEBRADA SALVATIERRA RAI	99-9954	18.18	65.10	140	07/1990	04/1999	5
QUEBRADA BLANCA RAINGAGE	99-9956	18.17	65.10	200	07/1990	04/1999	5
PUEBLITO DEL RIO RAINGAG	99-9958	18.25	65.83	340	07/1990	04/1999	5
GURABO ABAJO RAINGAGE, G	99-9959	18.27	65.92	285	09/1990	04/1999	5
QUEBRADA ARENAS RAINGAGE	99-9960	18.12	65.95	274	07/1990	04/1999	5
LA PLAZA RAINGAGE, CAGUA	99-9961	18.13	66.05	450	07/1990	04/1999	5
JAGUEYES ABAJO RAINGAGE,	99-9963	18.28	66.08	200	10/1991	04/1999	4
BAIROA ARRIBA RAINGAGE,	99-9964	18.27	66.10	370	10/1991	04/1999	4
VAQUERIA EL MINO RAINGAG	99-9965	18.22	66.07	120	10/1991	04/1999	5
BO. BEATRIZ RAINGAGE, CA	99-9966	18.18	66.08	400	10/1991	04/1999	5

BO. MONTONES RAINGAGE LA	99-9967	18.17	65.92	190	10/1991	04/1999	5
LAS PIEDRAS CONSTRUCTION	99-9968	18.20	65.83	113	10/1991	04/1999	5
BARRIO APEADERO RAINGAGE	99-9970	18.17	66.47	404	09/1996	04/1999	1
LAS CURIAS RAINGAGE NR C	99-9971	18.33	66.03	47	05/1997	04/1999	4

Appendix B. Merged daily stations in Puerto Rico and U.S. Virgin Islands

station id	**merged station**	**station name**
66-8126	66-8122	Rincon Power Plant
66-0974	66-7898	Borinquen Airport
66-0426	66-0849	Aricebo Observatory
66-8684	66-3871	Saltillo 2 Adjuntas
66-4910	66-4911	Juyuya
66-6514	66-6740	Negro Corozal
66-1536	66-0842	Candelaria Toa Baja
66-8306	66-8301	Rio Piedras Exp Station
66-6427	66-8745	Naguabo 3E
66-1309	66-1300, 66-1301	Caguas 1W
66-9432	66-4260	Toro Negro Forest
66-9860	66-9862	Yauco 1NW
66-2825	66-2823	Comerio Falls Plant 2
66-9766	66-9763	Vieques Island
66-8536	66-8535 (1966-1975)	Sabana Grande
66-0900	66-8757 (1970-1973)	Benavente Hormigueros
66-7292	66-7348 (1968-1993)	Ponce 4E
67-1810	67-8621	Cotton Valley 2
67-2870	67-1333	Estate the Sight
67-4900	67-4600	Montpellier

Appendix C. Deleted USGS 15-minute stations

Station Name	ID	Lat	Long	Elev	start date	end date
SONADORA METEOROLOGICAL STA.	06-3435	18.32	65.82	366	05/1991	03/1996
BISLEY METEOROLOGICAL STATION	06-5549	18.30	65.75	482	06/1991	04/1999
METEOROLOGICAL STA. AT R. ICACOS	07-5001	18.27	65.78	600	04/1992	04/1999
METEOROLOGICAL STA. AT U	28-5001	18.35	64.98	24	10/1991	04/1999
METEOROLOGICAL STA. AT L	29-0001	18.33	64.80	46	03/1992	04/1999
USDA METEREOLOGICAL STATION	33-3904	17.72	64.80	40	05/1991	04/1999

Appendix D. Daily values estimated for missing or accumulated values during Hurricanes Bertha, Hortense, Georges. Included are station number, date of occurrence, and estimated precipitation amounts added to partial duration dataset for Hurricanes Bertha, Hortense, and Georges.

station	date	daily precipitation (inches)
	Hurricane Bertha	
66-3023	7/8/96	82
66-3023	7/9/96	91
66-3023	7/10/96	69
	Hurricane Hortense	
66-5020	9/9/96	8
66-5020	9/10/96	432
66-3023	9/9/96	0
66-3023	9/10/96	257
66-3023	9/11/96	223
66-7492	9/10/96	101
66-7492	9/11/96	96
66-7843	9/10/96	463
66-7843	9/11/96	12
66-9608	9/9/96	8
66-9608	9/10/96	474
66-3409	9/10/96	878
66-3409	9/11/96	72
66-8306	9/10/96	205
66-8306	9/11/96	5
66-6992	9/10/96	1349
66-6992	9/11/96	395
66-6805	9/9/96	567
66-6805	9/11/96	234
66-6805	9/12/96	9
	Hurricane Georges	
66-0152	9/20/98	0
66-0152	9/21/98	542
66-0152	9/22/98	239
66-0152	9/23/98	33
66-0152	9/24/98	17
66-9774	9/19/98	29
66-9774	9/20/98	0
66-9774	9/21/98	0
66-9774	9/22/98	1805
66-6983	9/22/98	852
66-6983	9/23/98	348
66-3023	9/21/98	16

66-3023	9/22/98	1140
66-3023	9/23/98	484
66-0053	9/21/98	10
66-0053	9/22/98	1406
66-0053	9/23/98	534
66-0053	9/24/98	0
66-0061	9/22/98	1857
66-0061	9/23/98	343
66-5097	9/21/98	19
66-5097	9/22/98	779
66-5097	9/23/98	123
66-4330	9/21/98	36
66-4330	9/22/98	1664
66-0426	9/21/98	26
66-0426	9/22/98	843
66-0426	9/23/98	26
66-7843	9/19/98	26
66-7843	9/20/98	3
66-7843	9/21/98	7
66-7843	9/22/98	364
66-4702	9/21/98	146
66-4702	9/22/98	169
66-4702	9/23/98	40
66-0974	9/20/98	67
66-0974	9/21/98	137
66-0974	9/22/98	158
66-0974	9/23/98	38
66-5807	9/22/98	16
66-5807	9/23/98	4

Appendix E. Tropical and extratropical storms that have affected Puerto Rico from 1899-1998. Storm types are as follows: hurricane (H), tropical storm (TS), tropical depression (TD), tropical wave (TW), and extratropical (EX).

	DATE	TYPE	STORM NAME
1	8/8/1899	H	NA
2	8/31/00	T	NA
3	10/25/00	T	NA
4	7/7/01	H	NA
5	9/11/01	T	NA
6	10/9/01	T	NA
7	7/19/03	T	NA
8	9/2/06	H	NA
9	9/10/08	H	NA
10	9/26/08	T	NA
11	8/22/09	H	NA
12	11/13/09	T	NA
13	9/6/10	H	NA
14	8/11/15	H	NA
15	7/13/16	T	NA
16	8/22/16	H	NA
17	10/9/16	H	NA
18	9/21/17	H	NA
19	9/11/18	T	NA
20	9/3/19	T	NA
21	9/10/21	H	NA
22	9/16/22	H	NA
23	8/18/24	T	NA
24	7/23/26	H	NA
25	8/4/28	T	NA
26	9/13/28	H	NA
27	9/2/30	H	NA
28	8/17/31	T	NA
29	9/10/31	H	NA
30	9/26/32	H	NA
31	7/14/33	T	NA
32	9/28/33	T	NA
33	8/8/38	T	NA
34	8/5/40	T	NA
35	11/4/42	T	NA

36	8/8/43	T	NA
37	8/14/43	T	NA
38	10/14/43	H	NA
39	7/12/44	TD	
40	8/3/45	T	NA
41	9/13/45	H	NA
42	10/17/47	H	NA
43	8/23/49	T	NA
44	9/3/49	T	NA
45	8/23/50	T	BAKER
46	11/30/50	EX	
47	9/23/52	T	CHARLIE
48	9/8/53	T	DOLLY
49	9/14/53	T	EDNA
50	9/23/53	TW	
51	8/31/54	TD	
52	9/11/55	T	HILDA
53	8/12/56	H	BETSY
54	2/17/79	T	EDITH
55	9/5/60	H	DONNA
56	8/27/61	TW	
57	10/2/61	T	FRANCES
58	9/26/63	H	EDITH
59	8/23/64	H	CLEO
60	8/26/66	H	FAITH
61	9/28/66	H	INEZ
62	9/9/67	H	BEULAH
63	10/9/70	TW	
64	8/30/74	T	CARMEN
65	9/15/75	TD... T	ELOISE
66	7/18/79	TD	
67	8/30/79	H	DAVID
68	9/4/79	T	FREDERIC
69	9/8/81	T	GERT
70	12/13/81	EX	
71	11/7/84	T... H	KLAUS
72	5/18/85	EX	
73	10/7/85	TW	
74	9/22/87	H	EMILY

75	12/8/87	EX	
76	9/11/88	H	GILBERT
77	8/25/88	TD	
78	9/18/89	H	HUGO
79	10/7/90	T	KLAUS
80	8/16/93	T	CINDY
81	9/5/95	H	LUIS
82	9/15/96	H	MARILYN
83	10/23/95	T	SEBASTIEN
84	7/8/96	H	BERTHA
85	9/10/96	H	HORTENSE
86	9/5/97	H	ERIKA
87	9/21/98	H	GEORGES

Appendix F. A description of L-moment statistics.

L-moment statistics are used for data quality-control and return frequency estimates (Hosking and Wallis 1997). The precipitation frequency estimates are developed from L-moment regional analyses. The L-moment analysis computes regional growth factors (RGFs) for the various return frequencies for each region. RGFs are used to compute higher return frequencies from 2-year values, which are most reliable. L-moment definitions and tests for Heterogeneity (H), Goodness-of-fit and Discordancy (D) are described here.

Heterogeneity.

Heterogeneity is a measure of between-site variations in sample L-moments for a group of sites with what would be expected for a homogeneous region (Hosking and Wallis 1997). The heterogeneity test within a region consists of three parts: H1 based on L-coefficient-of-variation (L-CV), H2 based on L-CV and L-skewness (L-SK) and H3 based on L-SK and L-kurtosis (L-KT). Earlier studies (Hosking and Wallis (1991) and conversations with Wallis (1993)) indicate that a threshold of 2 is reasonable, especially for precipitation data. Therefore, for each H-test, a value greater than 2 (H>2) indicates heterogeneity, rather than homogeneity (H<2). As precipitation data are highly variable in some cases, it is wise to combine the heterogeneity test with the physical reason to determine whether a site with high heterogeneity measure should be retained in the original proposed region. Therefore, the heterogeneity results were applied less strictly when testing a homogenous region.

Goodness-of-fit.

The approach for goodness-of-fit has been refined. Three methods are used in the selection of the best distribution in the precipitation frequency study.

1. Xtest: For this test, the regional average values of L-KT and L-SK are plotted as a point. The test then measures the “distance” in L-KT between that point and various theoretical probability distributions on an L-SK - L-KT scale. Monte Carlo simulation was used to obtain a standard deviation of the “distance” for comparison. The threshold of pass-or-fail for goodness-of-fit tests is 1.64 (absolute value, 90% confidence). A smaller distance indicates a better fit.

2. Four criteria test: This test measures the distances of the L-KT for all real data points in the region from various theoretical distributions. The best fit is based on four criteria: 1) the distance of the average L-KT of the points from theoretical distributions; 2) the absolute mean distance of L-KT from theoretical distributions ; 3) the average of absolute distances of L-KT from theoretical distributions; 4) the root-mean-square of the distances from each point of real data from theoretical distributions in L-KT. No

simulation took place.

3. Real-data-check: This test compares the empirical frequencies of the real data with the probabilistic quantiles for various theoretical distributions fitted to the data over all stations (Lin and Vogel 1993).

Discordancy.

The discordancy measure is used for data checking and quality control. In evaluating regions, it is also used to determine if a site had been assigned to the appropriate region. The measure is based on L-moments, specifically L-CV, L-SK and L-KT, which represent a point in 3-dimensional space, for each site. Discordancy is then a measure of the distance from each point to the cluster center of points for the sites in the given region. The cluster center is the unweighted mean of the three moments for the sites within the region being tested.